# 2: Neuroscience and Behavior

## CHAPTER OVERVIEW

Chapter 2 is concerned with the functions of the brain and its component neural systems, which provide the basis for all human behavior. Under the direction of the brain, the nervous and endocrine systems coordinate a variety of voluntary and involuntary behaviors and serve as the body's mechanisms for communication with the external environment.

The brain consists of the brainstem, the thalamus, the cerebellum, the limbic system, and the cerebral cortex. Knowledge of the workings of the brain has increased with advances in neuroscientific methods. Studies of split-brain patients have also given researchers a great deal of information about the specialized functions of the brain's right and left hemispheres.

Many students find the technical material in this chapter difficult to master. Not only are there many terms for you to remember, but you must also know the organization and function of the various divisions of the nervous system. Learning this material will require a great deal of rehearsal. Working the chapter review several times, drawing and labeling brain diagrams, and mentally reciting terms are all useful techniques for rehearsing this type of material.

NOTE: Answer guidelines for all Chapter 2 questions begin on page 59.

## CHAPTER REVIEW

First, skim each section, noting headings and boldface items. After you have read the section, review each objective by answering the fill-in and essay-type questions that follow it. As you proceed, evaluate your performance by consulting the answers beginning on page 59. Do not continue with the next section until you understand each answer. If you need to, review or reread the section in the textbook before continuing.

### Introduction (pp. 53–54)

> David Myers at times uses idioms that are unfamiliar to some readers. If you do not know the meaning of any of the following words, phrases, or expressions in the context in which they appear in the text, refer to page 68 for an explanation: *to shoot a basketball; an ill-fated theory; a wrong-headed theory.*

**Objective 1:** Explain why psychologists are concerned with human biology, and describe the ill-fated phrenology theory.

1. In the most basic sense, every idea, mood, memory, and behavior that an individual has ever experienced is a _____ phenomenon.
2. The theory that linked our mental abilities to bumps on the skull was _____.
3. Researchers who study the links between biology and behavior are called _____ _____.

## Neural Communication (pp. 54–61)

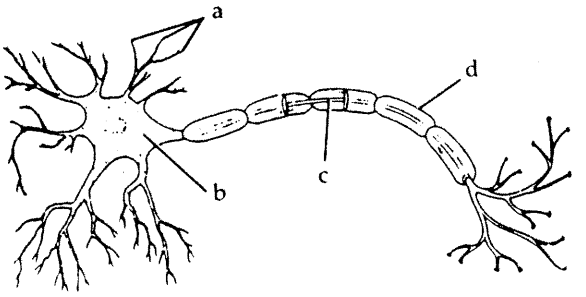
If you do not know the meaning of any of the following words, phrases, or expressions in the context in which they appear in the text, refer to pages 68–69 for an explanation: *happy fact of nature; building blocks; a sluggish 2 miles per hour to . . . a breakneck 200 or more miles; rather like manhole covers flipping open; boggles; somewhat like pushing a neuron's accelerator . . . more like pushing its brake; How do we distinguish a gentle touch from a big hug; "protoplasmic kisses"; "runner's high"; They trigger unpleasant, lingering aftereffects; Agonists excite . . . Antagonists inhibit; some chemicals can slither through this (blood-brain) barrier.*

**Objective 2:** Explain how viewing each person as a biopsychosocial system helps us understand human behavior, and discuss why researchers study other animals in search of clues to human neural processes.

1. We are each a _____ system, composed of _____ that are parts of larger _____, which are parts of an even larger _____.
2. Viewing each person in this way allows psychologists to study behavior and mental processes from multiple levels, noting how _____, _____, and _____-_____ systems work and interact.

**Objective 3:** Describe the parts of a neuron, and explain how its impulses are generated.

3. Our body's neural system is built from billions of nerve cells, or _____.
4. The extensions of a neuron that receive messages from other neurons are the _____.
5. The extension of a neuron that transmits information to other neurons is the _____; some of these extensions are insulated by a layer of fatty cells called the _____ _____, which helps speed the neuron's impulses.
6. Identify the major parts of the neuron diagrammed below:




a. _____ c. _____
b. _____ d. _____

7. The neural impulse, or _____ _____, is a brief electrical charge that travels down a(n) _____.
8. The fluid interior of a resting axon carries mostly _____ (positively/negatively) charged ions, while the fluid outside has mostly _____ (positively/negatively) charged ions. This polarization, called the _____ _____, occurs because the cell membrane is _____ _____.
9. An action potential occurs when the first part of the axon opens its gates and _____ (positively/negatively) charged ions rush in, causing that part of the neuron to become _____.
10. During the resting pause following an action potential, called the _____ _____, the neuron pumps _____ (positively/negatively) charged ions outside the cell.
11. In order to trigger a neural impulse, _____ signals minus _____ signals must exceed a certain intensity, called the _____. Increasing a stimulus above this level _____ (will/will not) increase the neural impulse's intensity. This phenomenon is called an _____-_____-_____ response.

12. The strength of a stimulus _____ (does/does not) affect the speed of a neural impulse.

**Objective 4:** Describe how nerve cells communicate.

13. The junction between two neurons is called a _____, and the gap is called the _____ _____. This discovery was made by _____.
14. The chemical messengers that convey information across the gaps between neurons are called _____. These chemicals unlock tiny channels on receptor sites, allowing electrically charged atoms (_____) to enter the neuron.
15. Neurotransmitters influence neurons either by _____ or _____ their readiness to fire. Excess neurotransmitters are reabsorbed by the sending neuron in a process called _____.

Outline the sequence of reactions that occur when a neural impulse is generated and transmitted from one neuron to another.

**Objective 5:** Explain how neurotransmitters affect behavior, and outline the effects of acetylcholine and the endorphins.

16. Among the neurotransmitters that researchers have pinpointed are _____, which influences movement, learning, attention, and emotion; _____, which affects mood, hunger, sleep, and arousal; _____, which helps control alertness and arousal; _____, which is an inhibitory neurotransmitter whose undersupply is linked to seizures, tremors, and insomnia; and _____, which is involved in memory.
17. A neurotransmitter that is important in muscle contraction is _____.
18. Naturally occurring opiatelike neurotransmitters that are present in the brain are called _____. When the brain is flooded with drugs such as _____ or _____, it may stop producing these neurotransmitters.

**Objective 6:** Explain how drugs and other chemicals affect neurotransmission, and describe the contrasting effects of agonists and antagonists.

19. Drugs that produce their effects by mimicking neurotransmitters are called _____. Drugs that block the effects of neurotransmitters by occupying their _____ _____ are called _____. While certain _____ drugs create a temporary "high" by mimicking the endorphins, the poison _____ produces paralysis by blocking the activity of the neurotransmitter ACh.
20. The molecular shape of some drugs prevents them from passing through the _____-_____ _____ by which the brain fences out unwanted chemicals.
21. The tremors of _____ disease are due to the death of neurons that produce the neurotransmitter _____. People with this condition can be helped to regain control over their muscles by taking _____.

## The Nervous System (pp. 61–65)

If you do not know the meaning of any of the following words, phrases, or expressions in the context in which they appear in the text, refer to pages 69–70 for an explanation: *Like an automatic pilot, this system may be consciously overridden; yield an ever-changing wiring diagram that dwarfs a powerful computer; information highway; The knee-jerk response . . . a headless warm body could do it; Being human takes a lot of nerve; work groups.*

**Objective 7:** Describe the nervous system's two major divisions, and identify the three types of neurons that transmit information through the system.

1. Taken altogether, the neurons of the body form the _____ _____.
2. The brain and spinal cord comprise the _____ nervous system. The neurons that link the brain and spinal cord to the body's sense receptors, muscles, and glands form the _____ nervous system.
3. Sensory and motor axons are bundled into electrical cables called _____.
4. Information arriving in the central nervous system from the body travels in _____ neurons. The neurons that enable internal communication within the central nervous system are called _____.
5. The central nervous system sends instructions to the body's tissues by means of _____ neurons.

**Objective 8:** Identify the subdivisions of the peripheral nervous system, and describe their functions.

6. The division of the peripheral nervous system that enables voluntary control of the skeletal muscles is the _____ nervous system.
7. Involuntary, self-regulating responses—those of the glands and muscles of internal organs—are controlled by the _____ nervous system.
8. The body is made ready for action by the _____ division of the autonomic nervous system.
9. The _____ division of the autonomic nervous system produces relaxation.

Describe and explain the sequence of physical reactions that occur in the body as an emergency is confronted and then passes.

**Objective 9:** Contrast the simplicity of the reflex pathways with the complexity of neural networks.

10. Automatic responses to stimuli, called _____, illustrate the work of the _____ _____. Simple pathways such as these are involved in the _____-_____ response and in the _____ reflex.

Beginning with the sensory receptors in the skin, trace the course of a spinal reflex as a person reflexively jerks his or her hand away from an unexpectedly hot burner on a stove.

11. To perform complex computations, neurons in the brain cluster into work groups called _____ _____.

## The Endocrine System (pp. 65–67)

If you do not know the meaning of any of the following words, phrases, or expressions in the context in which they appear in the text, refer to page 70 for an explanation: *kindred systems; Conducting and coordinating this whole electrochemical orchestra is that maestro we call the brain.*

**Objective 10:** Describe the nature and functions of the endocrine system and its interaction with the nervous system.

1. The body's chemical communication network is called the _____ _____.

This system transmits information through chemical messengers called _____ at a much _____ (faster/slower) rate than the nervous system, and its effects last _____ (a longer time/a shorter time).

2. In a moment of danger, the _____ glands release _____ and _____.
3. The most influential gland is the _____, which, under the control of an adjacent brain area called the _____, helps regulate _____ and the release of hormones by other endocrine glands.

Write a paragraph describing the feedback system that links the nervous and endocrine systems.

**Objective 11:** Describe several techniques for studying the brain.

1. Researchers sometimes study brain function by producing _____ or by selectively destroying brain cells. The oldest technique for studying the brain involves _____ _____ of patients with brain injuries or diseases.
2. The _____ is a recording of the electrical activity of the whole brain.
3. The technique depicting the level of activity of brain areas by measuring the brain's consumption of glucose is called the _____ _____.

Briefly explain the purpose of the PET scan.

## The Brain (pp. 67–92)

If you do not know the meaning of any of the following words, phrases, or expressions in the context in which they appear in the text, refer to pages 70–72 for an explanation: *we live in our heads; neural cartographers; snoop on the messages . . . and eavesdrop on the chatter of billions of neurons; the right side of the body is wired to . . .; Newer windows into the brain . . . Supermanlike; snapshots of the brain's changing activity provide . . . divides its labor; This peculiar cross-wiring is but one of many surprises the brain has to offer; . . . what London is to England's trains; the doughnut-shaped limbic system; reduced fits of rage; magnificent mistake; wrinkled organ, shaped somewhat like the meat of an oversized walnut; neural nannies; spine-tingling thrills; eyes in the back of our head; most widespread falsehoods; frontal lobes ruptured . . . Gage's moral compass; What you experience as . . . the visible tip of the information-processing iceberg; one patient even managed to quip that he had a "splitting headache"; When the "two minds" are at odds; pretzel-shaped finding . . . breadstick-shaped story; appear alike to the naked eye . . . harmony of the whole; southpaws; dwarfs.*

4. A technique that produces clearer images of the brain by using magnetic fields and radio waves is known as _____.
5. By taking pictures less than a second apart, the _____ _____ detects blood rushing to the part of the cortex thought to control the bodily activity being studied. Using this technique, researchers found that activity increases in the _____ _____ _____ when people experience conflicting _____.

**Objective 12:** Describe the components of the brainstem, and summarize the functions of the brainstem, thalamus, and cerebellum.

6. The oldest and innermost region of the brain is the _____.

7. At the base of the brainstem, where the spinal cord enters the skull, lies the _____, which controls _____ and _____. Just above this part is the _____, which helps coordinate movements.

8. Nerves from each side of the brain cross over to connect with the body's opposite side in the _____.

9. The _____ _____ is contained inside the brainstem and plays an important role in controlling _____. Electrically stimulating this area will produce an _____ animal. Lesioning this area will cause an animal to lapse into a _____.

10. At the top of the brainstem sits the _____, which serves as the brain's sensory switchboard, receiving information from all the senses except _____ and routing it to the regions dealing with those senses. These egg-shaped structures also receive replies from the higher regions, which they direct to the _____ and the _____.

11. At the rear of the brainstem lies the _____. It influences one type of _____ _____ and memory, but its major function is coordination of voluntary movement and _____ control.

12. The lower brain functions occur without _____ effort, indicating that our brains process most information _____ (inside/outside) of our awareness.

**Objective 13:** Describe the structures and functions of the limbic system, and explain how one of these structures controls the pituitary gland.

13. Between the brainstem and cerebral hemispheres is the _____ system. One component of this system that processes memory is the _____.

14. Aggression or fear will result from stimulation of different regions of the _____.

15. Amygdala lesions, produced by _____ techniques, have been used to treat violent humans. This treatment is controversial and _____ (widely/seldom) used today.

16. Below the thalamus is the _____, which regulates bodily maintenance behaviors such as _____, _____, and _____. This area also regulates behavior by secreting _____ that enable it to control the _____ gland. Olds and Milner discovered that this region also contains _____ centers, which animals will work hard to have stimulated.

17. Some researchers believe that alcoholism, drug abuse, binge eating, and other _____ disorders may stem from a genetic _____ _____ _____ in the natural brain systems for pleasure and well-being.

**Objective 14:** Define *cerebral cortex,* and explain its importance to the human brain.

18. The most complex functions of human behavior are linked to the most developed part of the brain, the _____ _____. This thin layer of interconnected neural cells is the body's ultimate control and _____-_____ center.

**Objective 15:** Identify the four lobes of the cerebral cortex.

19. The non-neural cells that support, protect, and nourish cortical neurons are called _____ _____. New evidence suggests that these cells may also play a role in _____ and _____.

20. Compared to the cortexes of lower mammals, the human cortex has a _____ (smoother/more wrinkled) surface. This _____ (increases/decreases) the overall surface area of our brains.

21. List the four lobes of the brain.

    a. _____ c. _____

    b. _____ d. _____

**Objective 16:** Summarize some of the findings on the functions of the motor cortex and the sensory cortex, and discuss the importance of the association areas.

22. Electrical stimulation of one side of the _____ cortex, an arch-shaped region at the back of the _____ lobe, will produce movement on the opposite side of the body. The more precise the control needed, the _____ (smaller/greater) amount of cortical space occupied. Research findings from studies involving _____ _____, in which recording electrodes are implanted in this area of animals' brains, raise hopes that people who are _____ may one day be able to control machines directly with their _____.

23. At the front of the parietal lobes lies the _____ cortex, which, when stimulated, elicits a sensation of _____.

24. The more sensitive a body region, the greater the area of _____ _____ devoted to it.

25. Visual information is received in the _____ lobes, whereas auditory information is received in the _____ lobes.

26. Areas of the brain that don't receive sensory information or direct movement but, rather, integrate and interpret information received by other regions are known as _____ _____. Approximately _____ of the human cortex is of this type. Such areas in the _____ lobe are involved in judging and planning, and in some aspects of personality. In the _____ lobe, these areas enable mathematical and spatial reasoning, and an area of the _____ lobe enables us to recognize faces.

**Objective 17:** Describe the five brain areas that would be involved if you read this sentence aloud.

27. Brain injuries may produce an impairment in language use called _____. Studies of people with such impairments have shown that _____ _____ is involved in producing speech, _____ _____ is involved in understanding speech, and the _____ _____ is involved in recoding printed words into auditory form.

28. Although the mind's subsystems are localized in particular brain regions, the brain acts as a _____ _____.

**Objective 18:** Discuss the brain's plasticity following injury or illness.

29. The quality of the brain that makes it possible for undamaged brain areas to take over the functions of damaged regions is known as _____. This quality is especially apparent in the brains of _____ (young children/adolescents/adults).

30. Although most severed neurons _____ (will/will not) regenerate, neural tissue can _____ in response to damage. New evidence suggests that adult mice and humans _____ (can/cannot) generate new brain cells in two older brain regions; research also reveals the existence of master _____ cells in the developing fetal brain that can develop into any type of brain cell.

**Objective 19:** Describe split-brain research, and explain how it helps us understand the functions of our left and right hemispheres.

31. Because damage to it will impair language and understanding, the _____ hemisphere came to be known as the _____ hemisphere.

32. In treating several patients with severe epilepsy, Vogel and Bogen separated the two hemispheres of the brain by cutting the _____ _____. When this structure is severed, the result is referred to as a _____ _____.

33. In a split-brain patient, only the _____ hemisphere will be aware of an unseen object held in the left hand. In this case, the person would not be able to _____ the object. When different words are shown in the left and right visual fields, if the patient fixates on a point on the center line between the fields, the patient will be able to say only the word shown on the _____.

Explain why a split-brain patient would be able to read aloud the word *pencil* flashed to his or her right visual field, but would be unable to identify a pencil by touch using only the left hand.

34. When the "two minds" of a split brain are at odds, the _____ hemisphere tries to rationalize what it doesn't understand. The _____ hemisphere often acts on autopilot. This phenomenon demonstrates that the _____ mind _____ (can/cannot) control our behavior.

35. Researchers studying undivided brains _____ (have/have not) found evidence of hemispheric specialization, which is also called _____. For example, pictures are recognized more rapidly when they are flashed to the _____ (right/left) hemisphere, whereas words are recognized faster and more accurately when flashed to the _____ (right/left) hemisphere.

36. Deaf people use the _____ hemisphere to process sign language.

**Objective 20:** Discuss the relationships among brain organization, handedness, and mortality.

37. In all cultures of the world, most of the human population is _____ (right/left)-handed. Genetic factors _____ (play/do not play) a role in handedness. This handedness bias is unique to humans and to our nearest _____ relatives.

38. With age, the percentage of left-handers _____ (increases/decreases). One controversial explanation of this difference is that _____ (right/left)-handers die at a younger age than their counterparts.

Identify several health risks that left-handers are more likely to have experienced.

## PROGRESS TEST 1

*Multiple-Choice Questions*

Circle your answers to the following questions and check them with the answers beginning on page 61. If your answer is incorrect, read the explanation for why it is incorrect and then consult the appropriate pages of the text (in parentheses following the correct answer).

1. The axons of certain neurons are covered by a layer of fatty tissue that helps speed neural transmission. This tissue is:
   a. the glia.
   b. the myelin sheath.
   c. acetylcholine.
   d. an endorphin.

2. Heartbeat, digestion, and other self-regulating bodily functions are governed by the:
   a. voluntary nervous system.
   b. autonomic nervous system.
   c. sympathetic division of the autonomic nervous system.
   d. somatic nervous system.

3. A strong stimulus can increase the:
   a. speed of the impulse the neuron fires.
   b. intensity of the impulse the neuron fires.
   c. number of times the neuron fires.
   d. threshold that must be reached before the neuron fires.

4. The pain of heroin withdrawal may be attributable to the fact that:
   a. under the influence of heroin the brain ceases production of endorphins.
   b. under the influence of heroin the brain ceases production of all neurotransmitters.
   c. during heroin withdrawal the brain's production of all neurotransmitters is greatly increased.
   d. heroin destroys endorphin receptors in the brain.

5. The brain research technique that involves monitoring the brain's usage of glucose is called (in abbreviated form) the:
   a. PET scan.
   b. fMRI.
   c. EEG.
   d. MRI.

6. In a resting state, the axon is:
   a. depolarized, with mostly negatively charged ions outside and positively charged ions inside.
   b. depolarized, with mostly positively charged ions outside and negatively charged ions inside.
   c. polarized, with mostly negatively charged ions outside and positively charged ions inside.
   d. polarized, with mostly positively charged ions outside and negatively charged ions inside.

7. Though there is no single "control center" for emotions, their regulation is primarily attributed to the brain region known as the:
   a. limbic system.
   b. reticular formation.
   c. brainstem.
   d. cerebellum.

8. Which is the correct sequence in the transmission of a simple reflex?
   a. sensory neuron → interneuron → sensory neuron
   b. interneuron → motor neuron → sensory neuron
   c. sensory neuron → interneuron → motor neuron
   d. interneuron → sensory neuron → motor neuron

9. Damage to _____ will usually cause a person to lose the ability to comprehend language.
   a. the angular gyrus
   b. Broca's area
   c. Wernicke's area
   d. frontal lobe association areas

10. Which of the following is typically controlled by the right hemisphere?
    a. language
    b. learned voluntary movements
    c. arithmetic reasoning
    d. perceptual tasks

11. Dr. Hernandez is studying neurotransmitter abnormalities in depressed patients. She would most likely describe herself as a:
    a. personality psychologist.
    b. phrenologist.
    c. psychoanalyst.
    d. biological psychologist.

12. The increasing complexity of animals' behavior is accompanied by a(n):
    a. increase in the size of the brainstem.
    b. decrease in the ratio of brain to body weight.
    c. increase in the size of the frontal lobes.
    d. increase in the amount of association area.

13. Voluntary movements, such as writing with a pencil, are directed by the:
    a. sympathetic nervous system.
    b. somatic nervous system.
    c. parasympathetic nervous system.
    d. autonomic nervous system.

14. A neuron will generate action potentials more often when it:
    a. remains below its threshold.
    b. receives an excitatory input.
    c. receives more excitatory than inhibitory inputs.
    d. is stimulated by a neurotransmitter.

15. Which is the correct sequence in the transmission of a neural impulse?
    a. axon → dendrite → cell body → synapse
    b. dendrite → axon → cell body → synapse
    c. synapse → axon → dendrite → cell body
    d. dendrite → cell body → axon → synapse

16. Chemical messengers produced by endocrine glands are called:
    a. agonists.
    b. neurotransmitters.
    c. hormones.
    d. enzymes.

17. Following a head injury, a person has ongoing difficulties staying awake. Most likely, the damage occurred to the:
    a. thalamus.
    b. corpus callosum.
    c. reticular formation.
    d. cerebellum.

18. (Thinking Critically) Based on research, which of the following seems true about the specialized functions of the right and left hemispheres?
    a. They are more clear-cut in men than in women.
    b. They are more clear-cut in women than in men.
    c. Most complex tasks emerge from the activity of one or the other hemisphere.
    d. Most complex activities emerge from the integrated activity of both hemispheres.

19. Cortical areas that are not primarily concerned with sensory, motor, or language functions are:
    a. called projection areas.
    b. called association areas.
    c. located mostly in the parietal lobe.
    d. located mostly in the temporal lobe.

20. In the brain, learning occurs as experience strengthens certain connections in cell work groups called:
    a. action potentials.
    b. neural networks.
    c. endocrine systems.
    d. dendrites.

### *Matching Items*

Match each structure or technique with its corresponding function or description.

*Structures*

_____ 1. hypothalamus
_____ 2. lesion
_____ 3. EEG
_____ 4. fMRI
_____ 5. reticular formation
_____ 6. MRI
_____ 7. thalamus
_____ 8. corpus callosum
_____ 9. cerebellum
_____ 10. amygdala
_____ 11. medulla

*Functions or Descriptions*

a. amplified recording of brain waves
b. technique that uses radio waves and magnetic fields to image brain anatomy
c. serves as sensory switchboard
d. contains reward centers
e. tissue destruction
f. technique that uses radio waves and magnetic fields to show brain function
g. helps control arousal
h. links the cerebral hemispheres
i. influences rage and fear
j. regulates breathing and heartbeat
k. enables coordinated movement

## PROGRESS TEST 2

Progress Test 2 should be completed during a final chapter review. Answer the following questions after you thoroughly understand the correct answers for the section reviews and Progress Test 1.

*Multiple-Choice Questions*

1. The visual cortex is located in the:
   a. occipital lobe.
   b. temporal lobe.
   c. frontal lobe.
   d. parietal lobe.

2. Which of the following is typically controlled by the left hemisphere?
   a. spatial reasoning
   b. word recognition
   c. the left side of the body
   d. perceptual skills

3. When Sandy scalded her toe in a tub of hot water, the pain message was carried to her spinal cord by the _____ nervous system.
   a. somatic
   b. sympathetic
   c. parasympathetic
   d. central

4. Which of the following are/is governed by the simplest neural pathways?
   a. emotions
   b. physiological drives, such as hunger
   c. reflexes
   d. movements, such as walking

5. Melissa has just completed running a marathon. She is so elated that she feels little fatigue or discomfort. Her lack of pain is probably the result of the release of:
   a. ACh.
   b. endorphins.
   c. dopamine.
   d. norepinephrine.

6. Parkinson's disease involves:
   a. the death of nerve cells that produce a vital neurotransmitter.
   b. impaired function in the right hemisphere only.
   c. impaired function in the left hemisphere only.
   d. excess production of the neurotransmitters dopamine and acetylcholine.

7. The technique that uses magnetic fields and radio waves to produce computer images of structures within the brain is called:
   a. the EEG.
   b. a lesion.
   c. a PET scan.
   d. MRI.

8. The myelin sheath that is on some neurons:
   a. increases the speed of neural transmission.
   b. slows neural transmission.
   c. regulates the release of neurotransmitters.
   d. does a. and c.

9. During an action potential, the electrical state of the axon becomes:
   a. polarized, as positively charged ions are admitted.
   b. polarized, as negatively charged ions are admitted.
   c. depolarized, as positively charged ions are admitted.
   d. depolarized, as negatively charged ions are admitted.

10. The neurotransmitter acetylcholine (ACh) is most likely to be found:
    a. at the junction between sensory neurons and muscle fibers.
    b. at the junction between motor neurons and muscle fibers.
    c. at junctions between interneurons.
    d. in all of the above locations.

11. The gland that regulates body growth is the:
    a. adrenal.
    b. thyroid.
    c. hypothalamus.
    d. pituitary.

12. Epinephrine and norepinephrine are _____ that are released by the _____ gland.
    a. neurotransmitters; pituitary
    b. hormones; pituitary
    c. neurotransmitters; thyroid
    d. hormones; adrenal

13. Jessica experienced difficulty keeping her balance after receiving a blow to the back of her head. It is likely that she injured her:
    a. medulla.
    b. thalamus.
    c. hypothalamus.
    d. cerebellum.

14. Moruzzi and Magoun caused a cat to lapse into a coma by severing neural connections between the cortex and the:
    a. reticular formation.
    b. hypothalamus.
    c. thalamus.
    d. cerebellum.

15. Research has found that the amount of representation in the motor cortex reflects the:
    a. size of the body parts.
    b. degree of precise control required by each of the parts.
    c. sensitivity of the body region.
    d. area of the occipital lobe being stimulated by the environment.

16. The effect of a drug that is an agonist is to:
    a. cause the brain to stop producing certain neurotransmitters.
    b. mimic a particular neurotransmitter.
    c. block a particular neurotransmitter.
    d. disrupt a neuron's all-or-none firing pattern.

17. The nerve fibers that enable communication between the right and left cerebral hemispheres and that have been severed in split-brain patients form a structure called the:
    a. reticular formation.
    b. association areas.
    c. corpus callosum.
    d. parietal lobes.

18. Beginning at the front of the brain and moving toward the back of the head, then down the skull and back around to the front, which of the following is the correct order of the cortical regions?
    a. occipital lobe; temporal lobe; parietal lobe; frontal lobe
    b. temporal lobe; frontal lobe; parietal lobe; occipital lobe
    c. frontal lobe; occipital lobe; temporal lobe; parietal lobe
    d. frontal lobe; parietal lobe; occipital lobe; temporal lobe

19. Following a nail gun wound to his head, Jack became more uninhibited, irritable, dishonest, and profane. It is likely that his personality change was the result of injury to his:
    a. parietal lobe.
    b. temporal lobe.
    c. occipital lobe.
    d. frontal lobe.

20. Three-year-old Marco suffered damage to the speech area of the brain's left hemisphere when he fell from a swing. Research suggests that:
    a. he may never speak again.
    b. his motor abilities may improve so that he can easily use sign language.
    c. his right hemisphere may take over much of the language function.
    d. his earlier experience with speech may enable him to continue speaking.

*Matching Items*

Match each structure or term with its corresponding function or description.

*Structures or Terms*

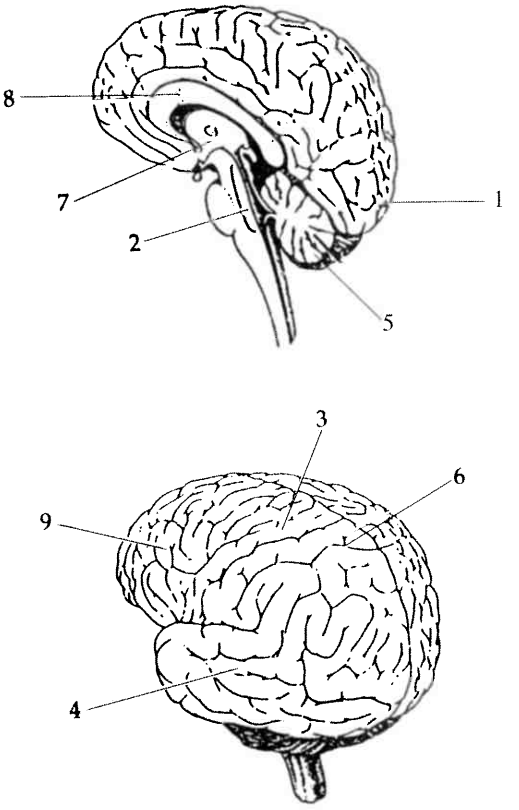
_____ 1. right hemisphere
_____ 2. brainstem
_____ 3. glial cells
_____ 4. aphasia
_____ 5. plasticity
_____ 6. Broca's area
_____ 7. Wernicke's area
_____ 8. limbic system
_____ 9. association areas
_____ 10. left hemisphere
_____ 11. angular gyrus

*Functions or Descriptions*

a. controls speech production
b. specializes in rationalizing reactions
c. translates writing into speech
d. specializes in spatial relations
e. brain cells that provide nutrients and insulating myelin
f. language disorder
g. oldest part of the brain
h. regulates emotion
i. the brain's capacity for modification
j. responsible for language comprehension
k. brain areas involved in higher mental functions

In the diagrams to the right, the numbers refer to brain locations that have been damaged. Match each location with its probable effect on behavior.

| *Location* | *Behavioral Effect* |
|---|---|
| _____ 1. | a. vision disorder |
| _____ 2. | b. insensitivity to touch |
| _____ 3. | c. motor paralysis |
| _____ 4. | d. hearing problem |
| _____ 5. | e. lack of coordination |
| _____ 6. | f. abnormal hunger |
| _____ 7. | g. split brain |
| _____ 8. | h. sleep/arousal disorder |
| _____ 9. | i. altered personality |




## PSYCHOLOGY APPLIED

Answer these questions the day before an exam as a final check on your understanding of the chapter's terms and concepts.

*Multiple-Choice Questions*

1. A biological psychologist would be *more* likely to study:
   a. how you learn to express emotions.
   b. how to help people overcome emotional disorders.
   c. life-span changes in the expression of emotion.
   d. the chemical changes that accompany emotions.

2. The part of the human brain that is most like that of a fish is the:
   a. cortex.
   b. limbic system.
   c. brainstem.
   d. right hemisphere.

3. You are able to pull your hand quickly away from hot water before pain is felt because:
   a. movement of the hand is a reflex that involves intervention of the spinal cord only.
   b. movement of the hand does not require intervention by the central nervous system.
   c. the brain reacts quickly to prevent severe injury.
   d. the autonomic division of the peripheral nervous system intervenes to speed contraction of the muscles of the hand.

4. In order to pinpoint the location of a tumor, a neurosurgeon electrically stimulated parts of the patient's sensory cortex. If the patient was conscious during the procedure, which of the following was probably experienced?
   a. "hearing" faint sounds
   b. "seeing" random visual patterns
   c. movement of the arms or legs
   d. a sense of having the skin touched

5. If Dr. Rogers wishes to conduct an experiment on the effects of stimulating the reward centers of a rat's brain, he should insert an electrode into the:
   a. thalamus.
   b. sensory cortex.
   c. hypothalamus.
   d. corpus callosum.

6. A split-brain patient has a picture of a knife flashed to her left hemisphere and that of a fork to her right hemisphere. She will be able to:
   a. identify the fork using her left hand.
   b. identify a knife using her left hand.
   c. identify a knife using either hand.
   d. identify a fork using either hand.

7. Several shy neurons send an inhibitory message to neighboring neuron Joni. At the same time, a larger group of party-going neurons send Joni excitatory messages. What will Joni do?
   a. fire, assuming that her threshold has been reached
   b. not fire, even if her threshold has been reached
   c. enter a refractory period
   d. become hyperpolarized

8. Following Jayshree's near-fatal car accident, her physician noticed that the pupillary reflex of her eyes was abnormal. This *may* indicate that Jayshree's _____ was damaged in the accident.
   a. occipital cortex
   b. autonomic nervous system
   c. left temporal lobe
   d. cerebellum

9. Anton is applying for a technician's job with a neurosurgeon. In trying to impress his potential employer with his knowledge of the brain, he says, "After my father's stroke I knew immediately that the blood clot had affected his left cerebral hemisphere because he no longer recognized a picture of his friend." Should Anton be hired?
   a. Yes. Anton obviously understands brain structure and function.
   b. No. The right hemisphere, not the left, specializes in picture recognition.
   c. Yes. Although blood clots never form in the left hemisphere, Anton should be rewarded for recognizing the left hemisphere's role in picture recognition.
   d. No. Blood clots never form in the left hemisphere, and the right hemisphere is more involved than the left in recognizing pictures.

10. Which of the following is *not* true regarding brain organization and handedness?
    a. If a person has a left-handed identical twin, odds are that he or she will also be left-handed.
    b. Right-handedness is far more common than left-handedness throughout the world.
    c. On average, right-handers live longer than left-handers.
    d. Left-handers are more common than usual among people with reading disabilities.

11. Dr. Johnson briefly flashed a picture of a key in the right visual field of a split-brain patient. The patient could probably:
    a. verbally report that a key was seen.
    b. write the word *key* using the left hand.
    c. draw a picture of a key using the left hand.
    d. do none of the above.

12. In primitive vertebrate animals, the brain primarily regulates _____ ; in lower mammals, the brain enables _____ .
    a. emotion; memory
    b. memory; emotion
    c. survival functions; emotion
    d. reproduction; emotion

13. Since Malcolm has been taking a drug prescribed by his doctor, he no longer enjoys the little pleasures of life, such as eating and drinking. His doctor explains that this is because the drug:
    a. triggers release of dopamine.
    b. inhibits release of dopamine.
    c. triggers release of ACh.
    d. inhibits release of ACh.

14. A scientist from another planet wishes to study the simplest brain mechanisms underlying emotion and memory. You recommend that the scientist study the:
    a. brainstem of a frog.
    b. limbic system of a dog.
    c. cortex of a monkey.
    d. cortex of a human.

15. Which of the following was a major problem with phrenology?
    a. It was "ahead of its time" and no one believed it could be true.
    b. The brain is not neatly organized into structures that correspond to our categories of behavior.
    c. The brains of humans and animals are much less similar than the theory implied.
    d. All of the above were problems with phrenology.

16. I am a relatively slow-acting (but long-lasting) chemical messenger carried throughout the body by the bloodstream. What am I?
    a. a hormone
    b. a neurotransmitter
    c. acetylcholine
    d. dopamine

17. Your brother has been taking prescription medicine and experiencing a number of unpleasant side effects, including unusually rapid heartbeat and excessive perspiration. It is likely that the medicine is exaggerating activity in the:
    a. reticular formation.
    b. sympathetic nervous system.
    c. parasympathetic nervous system.
    d. amygdala.

18. Dr. Frankenstein made a mistake during neurosurgery on his monster. After the operation, the monster "saw" with his ears and "heard" with his eyes. It is likely that Dr. Frankenstein "rewired" neural connections in the monster's:
    a. hypothalamus.
    b. cerebellum.
    c. amygdala.
    d. thalamus.

19. A bodybuilder friend suddenly seems to have grown several inches in height. You suspect that your friend's growth spurt has occurred because he has been using drugs that affect the:
    a. pituitary gland.
    b. thalamus.
    c. adrenal glands.
    d. medulla.

20. Raccoons have much more precise control of their paws than dogs. You would expect that raccoons have more cortical space dedicated to "paw control" in the _____ of their brains.
    a. frontal lobes
    b. parietal lobes
    c. temporal lobes
    d. occipital lobes

*Essay Question*

Discuss how the endocrine and nervous systems become involved when a student feels stress—such as that associated with an upcoming final exam. (Use the space below to list the points you want to make, and organize them. Then write the essay on a separate sheet of paper.)

## KEY TERMS

*Writing Definitions*

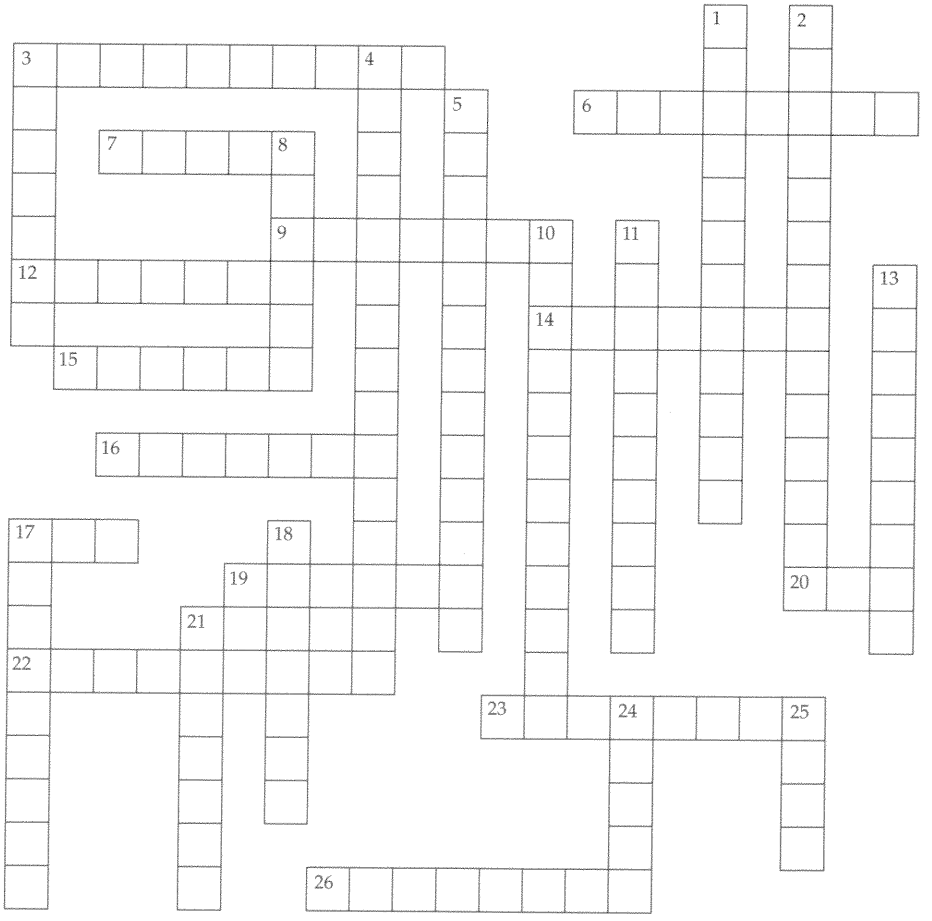
Using your own words, on a piece of paper write a brief definition or explanation of each of the following terms.

1. biological psychology
2. neuron
3. dendrites
4. axon
5. myelin sheath
6. action potential
7. threshold
8. synapse
9. neurotransmitters
10. acetylcholine (ACh)
11. endorphins
12. nervous system
13. central nervous system (CNS)
14. peripheral nervous system (PNS)
15. nerves
16. sensory neurons
17. interneurons
18. motor neurons
19. somatic nervous system
20. autonomic nervous system
21. sympathetic nervous system
22. parasympathetic nervous system
23. reflex

24. neural networks
25. endocrine system
26. hormones
27. adrenal glands
28. pituitary gland
29. lesion
30. electroencephalogram (EEG)
31. PET (positron emission tomography) scan
32. MRI (magnetic resonance imaging)
33. fMRI (functional MRI)
34. brainstem
35. medulla
36. reticular formation
37. thalamus
38. cerebellum
39. limbic system
40. amygdala
41. hypothalamus
42. cerebral cortex
43. glial cells
44. frontal lobes
45. parietal lobes
46. occipital lobes
47. temporal lobes
48. motor cortex
49. sensory cortex
50. association areas
51. aphasia
52. Broca's area
53. Wernicke's area
54. plasticity
55. corpus callosum
56. split brain

*Cross-Check*

As you learned in the Prologue, reviewing and overlearning of material are important to the learning process. After you have written the definitions of the key terms in this chapter, you should complete the crossword puzzle to ensure that you can reverse the process—recognize the term, given the definition.



ACROSS

3. The division of the nervous system that connects the brain and spinal cord to the body's sense receptors, muscles, and glands.
6. Located on the sides of the brain, these lobes contain the auditory areas, which receive information from the ears.
7. Located at the back of the frontal lobe, the part of the cortex that controls voluntary movement.
9. Located just behind the forehead, these lobes are involved in speaking and muscle movements and in making plans and judgments.
12. Glands that produce the hormones epinephrine and norepinephrine.

14. Located in the brainstem, this structure controls breathing and heartbeat.
15. The thin outer covering of the cerebral hemispheres.
16. Junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron.
17. Amplified recording of the waves of electrical activity of the brain.
19. Destruction of tissue.
20. Technique that uses magnetic fields and radio waves to produce computer-generated images of brain structures.
22. Located at the back and base of the brain, these lobes contain the visual cortex, which receives information from the eyes.
23. The part of the limbic system involved in regulation of the emotions of fear and rage.
26. Situated between the frontal and occipital lobes, these lobes contain the sensory cortex.

DOWN

1. Limbic system structure that regulates hunger, thirst, and body temperature and contains the so-called reward centers of the brain.
2. Large band of neural fibers that links the right and left hemispheres.
3. Technique that measures the levels of activity of different areas of the brain by tracing their consumption of a radioactive form of glucose.
4. Neural impulse generated by the movement of positively charged atoms in and out of channels in the axon's membrane.
5. Neurotransmitter that triggers muscle contractions.
8. Simple, automatic, inborn response to a sensory stimulus.
10. Doughnut-shaped neural system that plays an important role in the regulation of emotions and basic physiological drives.
11. Natural opiatelike neurotransmitters linked to pain control and to pleasure.
13. Division of the peripheral nervous system that controls the glands and the muscles of internal organs.
17. The body's slower chemical communication system, consisting of glands that secrete hormones into the bloodstream.
18. The brain and spinal cord, collectively, are the _____ nervous system.
21. An impairment of language as a result of damage to any of several cortical areas.
24. More numerous than cortical neurons, these cells of the brain guide neural connections and provide nutrients and insulating myelin.
25. Extension of a neuron that sends impulses to other nerve cells or to muscles or glands.

# ANSWERS

## Chapter Review

*Introduction*

1. biological
2. phrenology
3. biological psychologists

*Neural Communication*

1. biopsychosocial; subsystems; systems; system
2. biological; psychological; social-cultural
3. neurons
4. dendrites
5. axon; myelin sheath
6. **a.** dendrites
   **b.** cell body
   **c.** axon
   **d.** myelin sheath
7. action potential; axon
8. negatively; positively; resting potential; selectively permeable
9. positively; depolarized
10. refractory period; positively
11. excitatory; inhibitory; threshold; will not; all-or-none
12. does not
13. synapse; synaptic cleft (gap); Sir Charles Sherrington
14. neurotransmitters; ions
15. exciting; inhibiting; reuptake

A neural impulse is generated by excitatory signals minus inhibitory signals exceeding a certain threshold. The stimuli are received through the dendrites, combined in the cell body, and electrically transmitted in an all-or-none fashion down the length of the axon. When the combined signal reaches the end of the axon, chemical messengers called neurotransmitters are released into the synaptic cleft, or gap, between two neurons. Neurotransmitter molecules bind to receptor sites on the dendrites of neighboring neurons and have either an excitatory or inhibitory influence on that neuron's tendency to generate its own neural impulse.

16. dopamine; serotonin; norepinephrine; gamma-aminobutyric acid (GABA); glutamate
17. acetylcholine (ACh)

18. endorphins; heroin; morphine
19. agonists; receptor sites; antagonists; opiates; curare
20. blood-brain barrier
21. Parkinson's; dopamine; L-dopa

*The Nervous System*

1. nervous system
2. central; peripheral
3. nerves
4. sensory; interneurons
5. motor
6. somatic
7. autonomic
8. sympathetic
9. parasympathetic

The sympathetic division of the autonomic nervous system becomes aroused in response to an emergency. The physiological changes that occur include accelerated heartbeat, elevated blood sugar, dilation of arteries, slowing of digestion, and increased perspiration to cool the body. When the emergency is over, the parasympathetic nervous system produces the opposite physical reactions.

10. reflexes; spinal cord; knee-jerk; pain

From sensory receptors in the skin the message travels via sensory neurons to an interneuron in the spinal cord, which in turn activates a motor neuron. This motor neuron causes the muscles in the hand to contract, and the person jerks his or her hand away from the heat.

11. neural networks

*The Endocrine System*

1. endocrine system; hormones; slower; a longer time
2. adrenal; epinephrine; norepinephrine
3. pituitary; hypothalamus; growth

The hypothalamus in the brain influences secretions by the pituitary. The pituitary regulates other endocrine glands, which release hormones that influence behavior. The hypothalamus monitors these changes in blood chemistry and thereby adjusts its inputs to the pituitary.

*The Brain*

1. lesions; clinical observation
2. electroencephalogram (EEG)
3. PET scan

By depicting the brain's consumption of radioactively labeled glucose, the PET scan allows researchers to see which brain areas are most active as a person performs various tasks. This provides additional information on the specialized functions of various regions of the brain.

4. MRI (magnetic resonance imaging)
5. functional MRI; anterior cingulate cortex; urges
6. brainstem
7. medulla; breathing; heartbeat; pons
8. brainstem
9. reticular formation; arousal; alert (awake); coma
10. thalamus; smell; medulla; cerebellum
11. cerebellum; nonverbal learning; balance
12. conscious; outside
13. limbic; hippocampus
14. amygdala
15. psychosurgery; seldom
16. hypothalamus; hunger, thirst, body temperature (or sex); hormones; pituitary; reward
17. addictive; reward deficiency syndrome
18. cerebral cortex; information-processing
19. glial cells; learning; thinking
20. more wrinkled; increases
21. **a.** frontal lobe
    **b.** parietal lobe
    **c.** occipital lobe
    **d.** temporal lobe
22. motor; frontal; greater; neural prosthetics; paralyzed; thoughts (or brains)
23. sensory; touch
24. sensory cortex
25. occipital; temporal
26. association areas; three-fourths; frontal; parietal; temporal
27. aphasia; Broca's area; Wernicke's area; angular gyrus
28. unified whole
29. plasticity; young children
30. will not; reorganize; can; stem
31. left; dominant (major)
32. corpus callosum; split brain
33. right; name; right

The word *pencil* when flashed to a split-brain patient's right visual field would project only to the opposite, or left, hemisphere of the patient's brain.

Because the left hemisphere contains the language control centers of the brain, the patient would be able to read the word aloud. The left hand is controlled by the right hemisphere of the brain. Because the right hemisphere would not be aware of the word, it would not be able to guide the left hand in identifying a pencil by touch.

**34.** left; right; unconscious; can

**35.** have; lateralization; right; left

**36.** left

**37.** right; play; primate

**38.** decreases; left

Left-handers are more likely to have experienced premature or stressful births. They also have more headaches and accidents, use more tobacco and alcohol, and suffer more immune system problems.

## Progress Test 1

*Multiple-Choice Questions*

1. **b.** is the answer. (p. 55)
   **a.** Glial cells support and nourish nerve cells.
   **c.** Acetylcholine is a neurotransmitter that triggers muscle contraction.
   **d.** Endorphins are opiatelike neurotransmitters linked to pain control and to pleasure.
2. **b.** is the answer. The autonomic nervous system controls internal functioning, including heartbeat, digestion, and glandular activity. (p. 62)
   **a.** The functions mentioned are all automatic, not voluntary, so this answer cannot be correct.
   **c.** This answer is incorrect because most organs are affected by both divisions of the autonomic nervous system.
   **d.** The somatic nervous system transmits sensory input to the central nervous system and enables voluntary control of skeletal muscles.
3. **c.** is the answer. Stimulus strength can affect only the number of times a neuron fires or the number of neurons that fire. (p. 56)
   **a., b., & d.** These answers are incorrect because firing is an all-or-none response, so intensity remains the same regardless of stimulus strength. Nor can stimulus strength change the neuronal threshold or the impulse speed.
4. **a.** is the answer. Endorphins are neurotransmitters that function as natural painkillers. When the body has a supply of artificial painkillers such as heroin, endorphin production stops. (p. 59)
   **b.** The production of neurotransmitters other than endorphins does not cease.
   **c.** Neurotransmitter production does not increase during withdrawal.
   **d.** Heroin makes use of the same receptor sites as endorphins.
5. **a.** is the answer. The PET scan measures glucose consumption in different areas of the brain to determine their levels of activity. (p. 69)
   **b.** The fMRI compares MRI scans taken less than a second apart to reveal brain anatomy and function.
   **c.** The EEG is a measure of electrical activity in the brain.
   **d.** MRI uses magnetic fields and radio waves to produce computer-generated images of soft tissues of the body.
6. **d.** is the answer. (pp. 55–56)
7. **a.** is the answer. (p. 72)
   **b.** The reticular formation is linked to arousal.
   **c.** The brainstem governs the mechanisms of basic survival—heartbeat and breathing, for example—and has many other roles.
   **d.** The cerebellum coordinates movement output and balance.
8. **c.** is the answer. In a simple reflex, a sensory neuron carries the message that a sensory receptor has been stimulated to an interneuron in the spinal cord. The interneuron responds by activating motor neurons that will enable the appropriate response. (p. 63)
9. **c.** is the answer. Wernicke's area is involved in comprehension, and people with aphasia who have damage to Wernicke's area are unable to understand what is said to them. (p. 81)
   **a.** The angular gyrus translates printed words into speech sounds; damage would result in the inability to read aloud.
   **b.** Broca's area is involved in the physical production of speech; damage would result in the inability to speak fluently.
   **d.** The cortex's association areas are involved in, among other things, processing language; damage to these areas wouldn't specifically affect comprehension.
10. **d.** is the answer. (p. 88)
    **a.** In most persons, language is primarily a left hemisphere function.
    **b.** Learned movements are unrelated to hemispheric specialization.
    **c.** Arithmetic reasoning is generally a left hemisphere function.

11. **d.** is the answer. Biological psychologists study the links between biology (in this case, neurotransmitters) and psychology (depression, in this example). (p. 54)
12. **d.** is the answer. As animals increase in complexity, there is an increase in the amount of association areas. (p. 79)
    **a.** The brainstem controls basic survival functions and is not related to the complexity of an animal's behavior.
    **b.** The ratio of body and brain weight is a poor predictor of behavior complexity.
    **c.** The frontal lobe is concerned with personality, planning, and other mental functions, but its size is unrelated to intelligence or the complexity of behavior.
13. **b.** is the answer. (p. 62)
    **a., c., & d.** The autonomic nervous system, which is divided into the sympathetic and parasympathetic divisions, is concerned with regulating basic bodily maintenance functions.
14. **c.** is the answer. (p. 56)
    **a.** An action potential will occur only when the neuron's threshold is *exceeded*.
    **b.** An excitatory input that does not reach the neuron's threshold will not trigger an action potential.
    **d.** This answer is incorrect because some neurotransmitters inhibit a neuron's readiness to fire.
15. **d.** is the answer. A neuron receives incoming stimuli on its dendrites and cell body. These electrochemical signals are combined in the cell body, generating an impulse that travels down the axon, causing the release of neurotransmitter substances into the synaptic cleft or gap. (pp. 55–57)
16. **c.** is the answer. (p. 65)
    **a.** Agonists are drugs that excite neural firing by mimicking a particular neurotransmitter.
    **b.** Neurotransmitters are the chemicals involved in synaptic transmission in the nervous system.
    **d.** Enzymes are chemicals that facilitate various chemical reactions throughout the body but are not involved in communication within the endocrine system.
17. **c.** is the answer. The reticular formation plays an important role in arousal. (p. 71)
    **a.** The thalamus relays sensory input.
    **b.** The corpus callosum links the two cerebral hemispheres.
    **d.** The cerebellum is involved in coordination of movement output and balance.
18. **d.** is the answer. (p. 87)
19. **b.** is the answer. Association areas interpret, integrate, and act on information from other areas of the cortex. (p. 79)
20. **b.** is the answer. (p. 64)
    **a.** Action potentials are neural impulses that occur in all forms of communication in the nervous system.
    **c.** The endocrine system is the body's glandular system of chemical communication.
    **d.** Dendrites are the branching extensions of neurons that receive messages from other nerve cells.

*Matching Items*

1. d (p. 73)
2. e (p. 68)
3. a (p. 68)
4. f (p. 69)
5. g (p. 71)
6. b (p. 69)
7. c (p. 72)
8. h (p. 84)
9. k (p. 72)
10. i (p. 72)
11. j (p. 71)

## Progress Test 2

*Multiple-Choice Questions*

1. **a.** is the answer. The visual cortex is located at the very back of the brain. (p. 76)
2. **b.** is the answer. (p. 88)
   **a., c., & d.** Spatial reasoning, perceptual skills, and the left side of the body are primarily influenced by the right hemisphere.
3. **a.** is the answer. Sensory neurons in the somatic nervous system relay such messages. (p. 62)
   **b. & c.** These divisions of the autonomic nervous system are concerned with the regulation of bodily maintenance functions such as heartbeat, digestion, and glandular activity.
   **d.** The spinal cord itself is part of the central nervous system, but the message is carried to the spinal cord by the somatic division of the peripheral nervous system.
4. **c.** is the answer. As automatic responses to stimuli, reflexes are the simplest complete units of behavior and require only simple neural pathways. (p. 63)
   **a., b., & d.** Emotions, drives, and voluntary movements are all behaviors that are much more complex than reflexes and therefore involve much more complicated neural pathways.
5. **b.** is the answer. Endorphins are neurotransmitters that function as natural painkillers and are evidently involved in the "runner's high" and other situations in which discomfort or fatigue is expected but not experienced. (p. 59)

**a.** ACh is a neurotransmitter involved in muscular control.
**c.** Dopamine is a neurotransmitter involved in, among other things, motor control.
**d.** Norepinephrine is an adrenal hormone released to help us respond in moments of danger.

6. **a.** is the answer. Parkinson's disease causes the death of brain tissue that produces dopamine. (p. 60)
**b. & c.** This disease affects both hemispheres of the cortex.
**d.** This disease causes insufficient production of the neurotransmitters.

7. **d.** is the answer. (p. 69)
**a.** The EEG is an amplified recording of the brain's electrical activity.
**b.** A lesion is destruction of tissue.
**c.** The PET scan is a visual display of brain activity that detects the movement of a radioactive form of glucose as the brain performs a task.

8. **a.** is the answer. (p. 55)
**c. & d.** Myelin sheaths are not involved in regulating the release of neurotransmitters.

9. **c.** is the answer. (pp. 55–56)

10. **b.** is the answer. ACh is a neurotransmitter that causes the contraction of muscle fibers when stimulated by motor neurons. This function explains its location. (p. 58)
**a. & c.** Sensory neurons and interneurons do not directly stimulate muscle fibers.

11. **d.** is the answer. The pituitary regulates body growth, and some of its secretions regulate the release of hormones from other glands. (p. 66)
**a.** The adrenal glands are stimulated by the autonomic nervous system to release epinephrine and norepinephrine.
**b.** The thyroid gland produces a hormone that controls the rates of various chemical reactions in the body.
**c.** The hypothalamus regulates the pituitary but does not itself directly regulate growth.

12. **d.** is the answer. Also known as adrenaline and noradrenaline, epinephrine and norepinephrine are hormones released by the adrenal glands. (p. 66)

13. **d.** is the answer. The cerebellum is involved in the coordination of voluntary muscular movements. (p. 72)
**a.** The medulla regulates breathing and heartbeat.
**b.** The thalamus relays sensory inputs to the appropriate higher centers of the brain.
**c.** The hypothalamus is concerned with the regulation of basic drives and emotions.

14. **a.** is the answer. The reticular formation controls arousal via its connections to the cortex. Thus, separating the two produces a coma. (p. 71)
**b., c., & d.** None of these structures controls arousal. The hypothalamus regulates hunger, thirst, sexual behavior, and other basic drives; the thalamus is a sensory relay station; and the cerebellum is involved in the coordination of voluntary movement.

15. **b.** is the answer. (pp. 77–78)
**c. & d.** These refer to the sensory cortex.

16. **b.** is the answer. (pp. 59–60)
**a.** Abuse of certain drugs, such as heroin, may have this effect.
**c.** This describes the effect of an antagonist.
**d.** Drugs do not have this effect on neurons.

17. **c.** is the answer. The corpus callosum is a large band of neural fibers linking the right and left cerebral hemispheres. To sever the corpus callosum is in effect to split the brain. (p. 84)

18. **d.** is the answer. The frontal lobe is in the front of the brain. Just behind is the parietal lobe. The occipital lobe is located at the very back of the head and just below the parietal lobe. Next to the occipital lobe and toward the front of the head is the temporal lobe. (p. 76)

19. **d.** is the answer. As demonstrated in the case of Phineas Gage, injury to the frontal lobe may produce such changes in personality. (p. 80)
**a.** Damage to the parietal lobe might disrupt functions involving the sensory cortex.
**b.** Damage to the temporal lobe might impair hearing.
**c.** Occipital damage might impair vision.

20. **c.** is the answer. (p. 82)

*Matching Items*

1. d (p. 75)
2. g (p. 71)
3. e (p. 75)
4. f (p. 80)
5. i (p. 82)
6. a (p. 81)
7. j (p. 81)
8. h (p. 72)
9. k (p. 79)
10. b (p. 75)
11. c (p. 81)

*Brain Damage Diagram (pp. 67–82)*

1. a
2. h
3. c
4. d
5. e
6. b
7. f
8. g
9. i

## Psychology Applied

*Multiple-Choice Questions*

1. **d.** is the answer. Biological psychologists study the links between biology (chemical changes in this example) and behavior (emotions in this example). (p. 54)
   **a., b., & c.** Experimental, clinical, and developmental psychologists would be more concerned with the learning of emotional expressions, the treatment of emotional disorders, and life-span changes in emotions, respectively.

2. **c.** is the answer. The brainstem is the oldest and most primitive region of the brain. It is found in lower vertebrates, such as fish, as well as in humans and other mammals. The structures mentioned in the other choices are associated with stages of brain evolution beyond that seen in the fish. (p. 70)

3. **a.** is the answer. Since this reflex is an automatic response and involves only the spinal cord, the hand is jerked away before the brain has even received the information that causes the sensation of pain. (p. 63)
   **b.** The spinal cord, which organizes simple reflexes such as this one, is part of the central nervous system.
   **c.** The brain is not involved in directing spinal reflexes.
   **d.** The autonomic nervous system controls the glands and the muscles of the internal organs; it does not influence the skeletal muscles controlling the hand.

4. **d.** is the answer. Stimulation of the sensory cortex elicits a sense of touch, as the experiments of Penfield demonstrated. (p. 78)
   **a., b., & c.** Hearing, seeing, or movement might be expected if the temporal, occipital, and motor regions of the cortex, respectively, were stimulated.

5. **c.** is the answer. As Olds and Milner discovered, electrical stimulation of the hypothalamus is a highly reinforcing event because it is the location of the animal's reward centers. The other brain regions mentioned are not associated with reward centers. (p. 73)

6. **a.** is the answer. The left hand, controlled by the right hemisphere, would be able to identify the fork, the picture of which is flashed to the right hemisphere. (pp. 84–85)

7. **a.** is the answer.(p. 56)
   **b.** Because she has reached her threshold, she will probably fire.
   **c.** The refractory period is a resting period. Because Joni has received a large number of excitatory messages, she will not be at rest.
   **d.** *Hyperpolarization* is not a term.

8. **b.** is the answer. Simple reflexes, such as this one, are governed by activity in the autonomic nervous system. (p. 62)
   **a.** The occipital lobes process sensory messages from the eyes; they play no role in the reflexive response of the pupils to light.
   **c.** The left temporal lobe specializes in processing language.
   **d.** The cerebellum specializes in coordinating movement.

9. **b.** is the answer. (p. 88)
   **a., c., & d.** The left hemisphere does not specialize in picture recognition. And blood clots can form anywhere in the brain.

10. **a.** is the answer. In fact, handedness is one of only a few traits that identical twins are not especially likely to share. (pp. 89–90)

11. **a.** is the answer. The right visual field projects directly to the verbal left hemisphere. (p. 85)
    **b. & c.** The left hand is controlled by the right hemisphere, which, in this situation, would be unaware of the word since the picture has been flashed to the left hemisphere.

12. **c.** is the answer. (p. 70)
    **d.** Reproduction is only one of the basic survival functions the brain regulates.

13. **b.** is the answer. (pp. 58, 74)
    **a.** By triggering release of dopamine, such a drug would probably *enhance* Malcolm's enjoyment of the pleasures of life.
    **c. & d.** ACh is the neurotransmitter at synapses between motor neurons and muscle fibers.

14. **b.** is the answer. The hippocampus of the limbic system is involved in processing memory. The amygdala of the limbic system influences fear and anger. (p. 72)
    **a.** The brainstem controls vital functions such as breathing and heartbeat; it is not directly involved in either emotion or memory.
    **c. & d.** These answers are incorrect because the limbic system is an older brain structure than the cortex. Its involvement in emotions and memory is therefore more basic than that of the cortex.

15. **b.** is the answer. (p. 54)
**a.** "Ahead of its time" implies the theory had merit, which later research clearly showed it did not. Moreover, phrenology *was* accepted as an accurate theory of brain organization by many scientists.
**c.** Phrenology said nothing about the similarities of human and animal brains.

16. **a.** is the answer. (p. 65)
**b., c., & d.** Acetylcholine and dopamine are fast-acting neurotransmitters released at synapses, not in the bloodstream.

17. **b.** is the answer. Sympathetic arousal produces several effects, including accelerated heartbeat and excessive perspiration. (p. 62)
**a.** Stimulation of the reticular formation increases alertness, but would not necessarily accelerate heartbeat or cause excessive perspiration.
**c.** Arousal of the parasympathetic nervous system would have effects opposite to those stated.
**d.** If the medication were affecting his amygdala, your brother might experience emotions such as anger or fear at illogical times.

18. **d.** is the answer. The thalamus relays sensory messages from the eyes, ears, and other receptors to the appropriate projection areas of the cortex. "Rewiring" the thalamus, theoretically, could have the effects stated in this question. (p. 72)
**a., b., & c.** These brain structures are not directly involved in brain processes related to sensation or perception.

19. **a.** is the answer. Hormones of the pituitary gland regulate body growth. (p. 66)
**b. & d.** Because they are not endocrine glands, the thalamus and medulla are not influenced by hormones.
**c.** The adrenal glands produce hormones that provide energy during emergencies; they are not involved in regulating body growth.

20. **a.** is the answer. The motor cortex, which determines the precision with which various parts of the body can be moved, is located in the frontal lobes. (p. 77)
**b.** The parietal lobes contain the sensory cortex, which controls sensitivity to touch.
**c.** The temporal lobes contain the primary projection areas for hearing and, on the left side, are also involved in language use.
**d.** The occipital lobes contain the primary projection areas for vision.

*Essay Question*

The body's response to stress is regulated by the nervous system. As the date of the exam approaches, the stressed student's cerebral cortex activates the hypothalamus, triggering the release of hormones that in turn activate the sympathetic branch of the autonomic nervous system and the endocrine system. The autonomic nervous system controls involuntary bodily responses such as breathing, heartbeat, and digestion. The endocrine system contains glands that secrete hormones into the bloodstream that regulate the functions of body organs.

In response to activation by the hypothalamus, the student's pituitary gland would secrete a hormone which in turn triggers the release of epinephrine, norepinephrine, and other stress hormones from the adrenal glands. These hormones would help the student's body manage stress by making nutrients available to meet the increased demands for energy stores the body often faces in coping with stress. As these hormones activate the sympathetic division of the autonomic system, the body's fight-or-flight response occurs, including increased heart rate, breathing, and blood pressure and the suppression of digestion. After the exam date has passed, the student's body would attempt to restore its normal, pre-stress state. The parasympathetic branch of the autonomic system would slow the student's heartbeat and breathing and digestive processes would no longer be suppressed, perhaps causing the student to feel hungry.

## Key Terms

*Writing Definitions*

1. **Biological psychology** is the study of the links between biology and behavior. (p. 54)
2. The **neuron**, or nerve cell, is the basic building block of the nervous system. (p. 55)
3. The **dendrites** of a neuron are the bushy, branching extensions that receive messages from other nerve cells and conduct impulses toward the cell body. (p. 55)
4. The **axon** of a neuron is the extension that sends impulses to other nerve cells or to muscles or glands. (p. 55)
5. The **myelin sheath** is a layer of fatty tissue that segmentally covers many axons and helps speed neural impulses. (p. 55)
6. An **action potential** is a neural impulse generated by the movement of positively charged atoms in and out of channels in the axon's membrane. (p. 55)
7. A neuron's **threshold** is the level of stimulation that must be exceeded in order for the neuron to fire, or generate an electrical impulse. (p. 56)

8. A **synapse** is the junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron. The tiny gap at this junction is called the synaptic gap or cleft. (p. 57)
9. **Neurotransmitters** are chemicals that are released into synaptic gaps and so *transmit neural messages* from neuron to neuron. (p. 57)
10. **Acetylcholine (ACh)** is a neurotransmitter that enables learning and memory and also triggers muscle contraction. (p. 58)
11. **Endorphins** are natural, opiatelike neurotransmitters linked to pain control and to pleasure. (p. 59)

    *Memory aid:* Endorphins *end* pain.
12. The **nervous system** is the speedy, electrochemical communication system, consisting of all the nerve cells in the peripheral and central nervous systems. (p. 61)
13. The **central nervous system (CNS)** consists of the brain and spinal cord; it is located at the *center*, or internal core, of the body. (p. 61)
14. The **peripheral nervous system (PNS)** includes the sensory and motor neurons that connect the central nervous system to the body's sense receptors, muscles, and glands; it is at the *periphery* of the body relative to the brain and spinal cord. (p. 61)
15. **Nerves** are bundles of neural axons, which are part of the PNS, that connect the central nervous system with muscles, glands, and sense organs. (p. 62)
16. **Sensory neurons** carry information from the sense receptors to the central nervous system for processing. (p. 62)
17. **Interneurons** are the neurons of the central nervous system that link the sensory and motor neurons in the transmission of sensory inputs and motor outputs. (p. 62)
18. **Motor neurons** carry information and instructions for action from the central nervous system to muscles and glands. (p. 62)
19. The **somatic nervous system** is the division of the peripheral nervous system that enables voluntary control of the skeletal muscles; also called the skeletal nervous system. (p. 62)
20. The **autonomic nervous system** is the division of the peripheral nervous system that controls the glands and the muscles of internal organs and thereby controls internal functioning; it regulates the *automatic* behaviors necessary for survival. (p. 62)
21. The **sympathetic nervous system** is the division of the autonomic nervous system that arouses the body, mobilizing its energy in stressful situations. (p. 62)
22. The **parasympathetic nervous system** is the division of the autonomic nervous system that calms the body, conserving its energy. (p. 62)
23. A **reflex** is a simple, automatic, inborn response to a sensory stimulus; it is governed by a very simple neural pathway. (p. 63)
24. **Neural networks** are interconnected neural cells, the specific connections of which are strengthened as learning occurs. (p. 64)
25. The **endocrine system**, the body's "slower" chemical communication system, consists of glands that secrete hormones into the bloodstream. (p. 65)
26. **Hormones** are chemical messengers, mostly those manufactured by the endocrine glands, that are produced in one tissue and circulate through the bloodstream to their target tissues, on which they have specific effects. (p. 65)
27. The **adrenal glands** produce epinephrine and norepinephrine, hormones that prepare the body to deal with emergencies or stress. (p. 66)
28. The **pituitary gland**, under the influence of the hypothalamus, regulates growth and controls other endocrine glands; sometimes called the "master gland." (p. 66)
29. A **lesion** is destruction of tissue; studying the consequences of lesions in different regions of the brain—both surgically produced in animals and naturally occurring—helps researchers to determine the normal functions of these regions. (p. 68)
30. An **electroencephalogram (EEG)** is an amplified recording of the waves of electrical activity of the brain. *Encephalo* comes from a Greek word meaning "related to the brain." (p. 68)
31. The **PET (positron emission tomography) scan** measures the levels of activity of different areas of the brain by tracing their consumption of a radioactive form of glucose, the brain's fuel. (p. 69)
32. **MRI (magnetic resonance imaging)** uses magnetic fields and radio waves to produce computer-generated images that show brain structures more clearly. (p. 71)
33. In a **fMRI (functional magnetic resonance imaging),** MRI scans taken less than a second apart are compared to reveal blood flow and, therefore, brain anatomy and function. (p. 69)

34. The **brainstem**, the oldest and innermost region of the brain, is an extension of the spinal cord and is the central core of the brain; its structures direct automatic survival functions. (p. 71)
35. Located in the brainstem, the **medulla** controls breathing and heartbeat. (p. 71)
36. Also part of the brainstem, the **reticular formation** is a nerve network that plays an important role in controlling arousal. (p. 71)
37. Located atop the brainstem, the **thalamus** routes incoming messages to the appropriate cortical centers and transmits replies to the medulla and cerebellum. (p. 72)
38. The **cerebellum** processes sensory input and coordinates movement output and balance. (p. 72)
39. A doughnut-shaped neural system, the **limbic system** is associated with emotions such as fear and aggression and basic physiological drives. (p. 72)

    *Memory aid:* Its name comes from the Latin word *limbus*, meaning "border"; the **limbic system** is at the border of the brainstem and cerebral hemispheres.
40. The **amygdala** is part of the limbic system and influences the emotions of fear and aggression. (p. 72)
41. Also part of the limbic system, the **hypothalamus** regulates hunger, thirst, body temperature, and sex; helps govern the endocrine system via the pituitary gland; and contains the so-called reward centers of the brain. (p. 73)
42. The **cerebral cortex** is a thin intricate covering of interconnected neural cells atop the cerebral hemispheres. The seat of information processing, the cortex is responsible for those complex functions that make us distinctively human. (p. 74)

    *Memory aid: Cortex* in Latin means "bark." As bark covers a tree, the **cerebral cortex** is the "bark of the brain."
43. More numerous than cortical neurons, the **glial cells** of the brain guide neural connections, provide nutrients and insulating myelin, and help remove excess ions and neurotransmitters. (p. 75)
44. Located at the front of the brain, just behind the forehead, the **frontal lobes** are involved in speaking and muscle movements and in making plans and judgments. (p. 76)
45. Situated between the frontal and occipital lobes, the **parietal lobes** contain the sensory cortex. (p. 76)
46. Located at the back and base of the brain, the **occipital lobes** contain the visual cortex, which receives information from the eyes. (p. 76)
47. Located on the sides of the brain, the **temporal lobes** contain the auditory areas, which receive information from the ears. (p. 76)

    *Memory aid:* The **temporal lobes** are located near the *temples.*
48. Located at the back of the frontal lobe, the **motor cortex** controls voluntary movement. (p. 77)
49. The **sensory cortex** is located at the front of the parietal lobes, just behind the motor cortex. It registers and processes body touch and movement sensations. (p. 78)
50. Located throughout the cortex, **association areas** of the brain are involved in higher mental functions, such as learning, remembering, and abstract thinking. (p. 79)

    *Memory aid:* Among their other functions, **association areas** of the cortex are involved in integrating, or *associating*, information from different areas of the brain.
51. **Aphasia** is an impairment of language as a result of damage to any of several cortical areas, including Broca's area and Wernicke's area. (p. 80)
52. **Broca's area**, located in the left frontal lobe, is involved in controlling the motor ability to produce speech. (p. 81)
53. **Wernicke's area,** located in the left temporal lobe, is involved in language comprehension and expression. (p. 81)
54. **Plasticity** is the brain's capacity for modification, as evidenced by brain reorganization following damage (especially in children). (p. 82)
55. The **corpus callosum** is the large band of neural fibers that links the right and left cerebral hemispheres. Without this band of nerve fibers, the two hemispheres could not interact. (p. 84)
56. **Split brain** is a condition in which the major connections between the two cerebral hemispheres (the corpus callosum) are severed, literally resulting in a split brain. (p. 84)

*Cross-Check*

**ACROSS**

**3.** peripheral
**6.** temporal
**7.** motor
**9.** frontal
**12.** adrenal
**14.** medulla
**15.** cortex
**16.** synapse
**17.** EEG
**19.** lesion
**20.** MRI
**22.** occipital
**23.** amygdala
**26.** parietal

**DOWN**

**1.** hypothalamus
**2.** corpus callosum
**3.** PET scan
**4.** action potential
**5.** acetylcholine
**8.** reflex
**10.** limbic system
**11.** endorphins
**13.** autonomic
**17.** endocrine
**18.** central
**21.** aphasia
**24.** glial
**25.** axon

## *FOCUS ON VOCABULARY AND LANGUAGE*

*Page 53: . . . to shoot a basketball. . . .* This means to throw the ball, in the game of basketball, through the hoop. Science today is intensely focused on (*riveted on*) research involving the brain and how it accomplishes a wide variety of mental and physical tasks.

*Page 53: . . . an ill-fated theory. . . .* Myers is referring to the theory that bumps or lumps on the skull could reveal our personality (*phrenology*). It was a theory destined for failure (*ill-fated*), despite its popularity during the early 1800s.

*Page 53 (caption):* A *wrongheaded* theory. Even though phrenology was without any scientific merit (*wrongheaded*), it did suggest the idea that different parts of the brain influence a variety of functions and behaviors.

### *Neural Communication*

*Page 54:* For scientists, it is a *happy fact of nature* that the information systems of humans and other animals operate similarly. . . . The structure and function of neurons are very similar in humans and other animals (e.g., squids and sea slugs) and this is a good thing (*a happy fact of nature*) for those researching the nervous system. Myers makes the important point about this similarity, noting that it would not be possible to tell the difference between a small piece of your brain tissue and that of a monkey.

*Page 55:* Its *building blocks* are **neurons,** or nerve cells. Building blocks are the basic or fundamental parts (e.g., bricks) that make up a structure (e.g., a house). The structure of our nervous system, or neural information system, is made up of neurons (*its building blocks*).

*Page 55: . . .* the neural impulse travels at speeds ranging from a *sluggish* 2 miles per hour to a *breakneck* 200 or more miles per hour. The speed of the neural impulse ranges from extremely slow (*sluggish*) to very fast (a *breakneck* speed). Compared to the speed of electricity or sophisticated electronics systems your neural impulses travel at a relatively slow pace.

*Page 56: . . .* The first bit of the axon opens its gates, *rather like manhole covers flipping open,* and positively charged sodium ions flood through the membrane. The circular metal tops that cover entrances to sewer lines, water pipes, etc., are called *manhole covers.* When a neuron fires the resting axon no longer blocks access to positive sodium ions (*the security parameters change*) and consequently the axon begins to open its gates in sequence, much like a series of lids that open in succession (*like manhole covers flipping open*) allowing sodium ions in. The sequential opening of each channel is like a chain reaction with each event affecting the next, and so on (*like dominoes falling, each one tripping the next*).

*Page 56:* The mind *boggles . . . Boggle* means to startle, alarm, or surprise. Our minds are amazed (*boggled*) by the astounding complexity and intricate activity of the brain and nervous system.

*Page 56:* Most of these signals are *excitatory, somewhat like pushing a neuron's accelerator.* Other signals are *inhibitory, more like pushing its brake.* Myers is making a comparison between the effect of a neuron firing and the effect of speeding up a car when accelerating (*excitatory effect*) or slowing it down by applying the brake (*inhibitory effect*). He also likens excitatory signals to those who love social gatherings (*party animals*), and inhibitory signals to those who do not (*party poopers*); if those who want to have a party outvote those who don't, then the party (*action potential*) will happen (i.e., *the party's on*).

*Page 56: How do we distinguish a gentle touch from a big hug?* This question is concerned with how we become aware of the magnitude of a stimulus, from a soft stroke or pat (*gentle touch*) to a strong embrace (*big hug*). The answer is that the intensity of the stimulus is a function of the number and frequency of neurons firing. A strong stimulus (*big hug*) does not initiate (*trigger*) a more powerful or faster impulse than a weak stimulus (*gentle touch*); rather, it triggers more neurons to fire, and to fire more often.

*Page 57:* . . . these near-unions of neurons—*"protoplasmic kisses"*. . . were another of nature's marvels. The reference here is to the fact that the axon terminal of one neuron is separated from the receiving neuron by a tiny space called the synaptic gap. Protoplasm is the material that constitutes all living cells, and the communication between cells is likened to a kiss between cells (*protoplasmic kisses*). The transmission between sender and receiver is via chemicals called neurotransmitters. The cells don't actually touch but send messages across the synaptic gap.

*Page 59:* . . . *"runner's high"* . . . This refers to the feeling of emotional well-being or euphoria (*high*) following vigorous exercise such as running or jogging and is the result of the release of opiatelike substances called endorphins.

*Page 59:* They *trigger* unpleasant, *lingering aftereffects.* For suppressing the body's own neurotransmitter production, *nature charges a price.* Mood-altering drugs, such as alcohol, nicotine, heroin, and morphine, all initiate (*trigger*) disagreeable changes that persist for a long period of time (*lingering aftereffects*). When flooded with these opiates, the brain stops producing its own endorphins (i.e., they suppress production), and for the addict who stops taking the drugs the cost may be a great deal of pain and agony (*nature charges a price*).

*Page 59: Agonists* excite. . . . *Antagonists* inhibit. An *agonist* drug molecule is enough like the neurotransmitter to imitate (*mimic*) its effects (for example, by producing a temporary euphoric feeling—a "high") or it may prevent (*block*) the *reuptake* of the neurotransmitter (for example, too much ACh flooding the synapses causes muscle contractions, convulsions, or even death). An *antagonist* drug, on the other hand, can stop (*inhibit*) the release of a neurotransmitter (for example, preventing the release of ACh from the sending neuron can cause paralysis), or it may *occupy* the receptor sites on the receiving neuron so the neuron can't fire (for example, toxins such as curare fill the ACh receptor sites, and paralysis will result when the neurons can't fire).

*Page 60:* But some chemicals can *slither through* this [blood-brain] barrier. The *blood-brain barrier* is a system that blocks or obstructs unwanted chemicals circulating in the blood from getting into the brain (*the brain fences them out*). Some neurotransmitter substances (chemicals) such as L-dopa can slide or slip smoothly (*slither*) through the blood-brain barrier. The brain then transforms this raw material into dopamine (which cannot cross the blood-brain barrier), allowing many Parkinson's patients to obtain better muscle control.

### *The Nervous System*

*Page 62:* Like an *automatic pilot,* this system may be consciously *overridden.* The autonomic nervous system automatically takes care of the operation of our internal organs much as a plane can be flown by the automatic (*or mechanical/computerized*) pilot. The system can, however, be consciously taken over (*overridden*) in the same way that the real pilot can take over flying the plane.

*Page 63:* Tens of billions of neurons, each communicating with thousands of other neurons, *yield an ever-changing wiring diagram that dwarfs a powerful computer.* The complexity of the central nervous system, which allows or makes possible (*enables*) our thinking, feeling, and behavior, is similar to the electronic circuitry (*wiring diagrams)* of the best computer, except, by comparison, the computer would appear to be extremely tiny or small (*dwarfed by*) and the brain's wiring would seem to be constantly modifying or altering itself (*ever-changing*).

*Page 63:* . . . *information highway.* . . . The spinal cord is similar to the freeway (*highway*), but instead of cars moving up and down, sensory and motor messages (*information*) travel between the peripheral nervous system and the brain. This information moves either up (*ascending*) to the brain or down (*descending*) from the brain.

*Page 63: The knee-jerk response,* for example, involves one such simple pathway; *a headless warm body could*

*do it.* When the patellar tendon of a bent knee is struck, the whole leg reflexively straightens out (*the knee-jerk response*). This automatic reaction is a function of a simple spinal reflex pathway so it does not require mediation by the brain (*a headless warm* [live] *body could do it*).

*Page 64:* Being human *takes a lot of nerve.* Myers is using humor to make a point here. The expression "it takes a lot of nerve" means to be very brave or courageous (another expression, "it takes a lot of guts," means the same thing!). Thus, when Myers states that being human takes a lot of nerve, the literal meaning in this context is that humans are made up of many, many nerves (the humor is derived from the double meaning).

*Page 64:* Neurons cluster into *work groups* called neural networks. Myers points out that the brain works much like a computer making many simultaneous computations. This is accomplished by neural networks which are clusters of interconnected neurons (*work groups*). Neurons work with nearby neurons for much the same reason people live in cities—it is easier for brief, quick interactions.

### *The Endocrine System*

*Page 65:* The endocrine system and nervous system are therefore *kindred* systems. These two systems are very similar and have a close relationship (*kindred systems*). The hormones of the endocrine system are chemically equivalent to neurotransmitters, but operate at a much slower speed. Messages in the nervous system move very rapidly (they zip along as fast as e-mail) compared to endocrine system messages which move relatively slowly (they trudge along like regular or "snail" mail).

*Page 67:* Conducting and coordinating this whole *electrochemical orchestra* is that *maestro* we call the brain. Myers is comparing the functioning of the neurotransmitters and hormones to a large group of musicians (*electrochemical orchestra*) whose movements and actions are directed by the conductor or master (*maestro*), the brain.

### *The Brain*

*Page 67: . . . we live in our heads.* What this means is that you subjectively feel that the essence of your being, your mind, resides in your brain, which is inside your head. The brain in our head allows us to function psychologically as well as physically: *the mind is what the brain does.*

*Page 68: The known universe's most amazing organ is being probed and mapped by a new generation of neural cartographers.* A cartographer is someone who prepares or makes maps. Myers is suggesting that the brain (*the known universe's most amazing organ*) is going to be graphically depicted (*mapped*) by a new younger group of neuroscientists (a new generation of neural *cartographers*).

*Page 68:* We can *snoop on* the messages of individual neurons and *eavesdrop on the chatter* of billions of neurons. With today's technological tools it is possible to unobtrusively view or spy on (*snoop on*) single nerve cells (neurons) as well as covertly listen to (*eavesdrop on*) the back-and-forth communication (*chatter*) of millions and millions of cells.

*Page 68: . . .* the right side of the body is *wired* to the brain's left side, and *vice versa.* This means that the functions of one side of the body are controlled by (*wired to*) the opposite side of the brain. The right side of the body is controlled by the left hemisphere, and the converse, or opposite, is also true (*vice versa*): the left side of the body is controlled by the brain's right hemisphere.

*Page 69: Newer windows into the brain* give us a *Supermanlike* ability to see inside the living brain. Modern technological means of viewing the brain (*new windows into the brain*), such as the PET scan, MRI, and fMRI, provide us with a greater than normal (*Supermanlike*) ability to look inside the cortex without destroying tissue. (*Note:* Superman is a comic-book, TV, and movie character with x-ray vision which allows him to see through solid matter.)

*Page 69:* Such *snapshots* of the brain's changing *activity* provide new insights into how the brain *divides its labor.* The MRI technique allows pictures (*snapshots*) to be taken of different brain areas at work (the brain *divides its labor*) while a person is carrying out various mental tasks.

*Page 71: This peculiar cross-wiring is but one of many surprises the brain has to offer.* In the brainstem most nerves from the left side of the body connect to the right side of the brain and those from the right connect to the left side of the brain. This strange (*peculiar*) traverse of nerves from one side to the other (*cross-wiring*), which occurs in the pons, is one of the many marvels or astonishing findings (*surprises*) about the brain.

*Page 72:* Think of the thalamus as being to sensory input what *London is to England's trains.* London is the relay center for trains going to all parts of the

country just as Chicago is the hub or relay center for many airlines flying to different parts of the United States. Myers uses this as an analogy for the thalamus, which receives messages from sensory neurons and sends them on, or relays them to higher brain areas (it also receives some of the higher brain's responses and directs them to the medulla and the cerebellum).

*Page 72:* . . . the *doughnut-shaped* **limbic system**. This system is in the shape of a ring (*doughnut-shaped*) and has three components: the **hippocampus,** which is involved in forming (*laying down*) new memories; the **amygdala,** which influences aggression and fear; and the **hypothalamus,** which regulates hunger, thirst, body temperature, and sexuality.

*Page 73:* In a few cases involving patients who suffered brain abnormalities, it [*"psychosurgery"*] *reduced fits of rage,* though sometimes with devastating side effects on the patient's everyday functioning. *Psychosurgery* refers to destruction (lesioning) of healthy brain tissue to achieve some psychological change in a patient, such as making a violent patient calm and relaxed (*reducing fits of rage*). Because there were also other severe changes (*side effects*), this drastic procedure is almost never used today.

*Page 74:* . . . they made *a magnificent mistake.* Olds and Milner accidentally discovered (*stumbled upon*) a brain area that provides a pleasurable reward and then went on to find other similar areas which they called *"pleasure centers."* Myers calls this a splendid and spectacular error (*a magnificent mistake*). When rats are allowed to stimulate these areas by pressing a bar or lever (*pedal*) they seem to prefer this to any other activity and will continue at a very rapid rate (*feverish pace*) until they are too tired to go on (*until they drop from exhaustion*).

*Page 75:* If you opened a human skull, exposing the brain, you would see a *wrinkled* organ, shaped somewhat like the *meat of an oversized walnut.* The human brain has a convoluted (*wrinkled*) surface, and the cerebral cortex is divided into two halves or hemispheres just like the two lobes of the edible portion (*the meat or seed*) in the shell of a very large (*oversized*) walnut.

*Page 75:* Glial cells are *neural nannies.* A *nanny* (or *nannie*) is a child's nursemaid and takes care of the relatively helpless child's needs. **Glial cells** perform in a similar way by looking after the needs of neurons which, like children, cannot feed or insulate themselves (they are *neural nannies*). Glial cells may also be involved (play a role) in learning and thinking.

*Page 77:* . . . *spine-tingling thrills* that music lovers enjoy . . . For some people, listening to music generates viscerally pleasurable sensations (*spine-tingling thrills*), which appear to involve the same reward systems that are stimulated by sex and pleasant-tasting foods. The point is that activities such as listening to music are relatively complex and engage multiple brain areas.

*Page 79:* In a sense, we *do* have *eyes in the back of our head!* The reference here is to the visual cortex (or occipital lobes) which processes visual information and is located at the rear of the brain. So, in a way seeing is not just done with the eyes but also involves specialized areas at the back of the brain.

*Page 79:* . . . one of pop psychology's most widespread *falsehoods:* that we ordinarily *use only 10 percent of our brains.* Research into the association areas of the brain showed that they don't have specific functions but rather are involved in many different operations such as interpreting, integrating, and acting on information processed by the sensory areas. The incorrect notion (*falsehood*) that *we use only 10 percent of our brains* may have arisen because early researchers were unsure about the function of the association areas. Remember, we use all of our brain, all the time. Damage to the association areas would result in very serious deficits.

*Page 80:* With his frontal lobes *ruptured,* Gage's *moral compass* became disconnected from his behavior. Phineas Gage's frontal lobes were severely damaged (*ruptured*) when the tamping iron shot through his head. As a result, he lost many of his normal inhibitions, which caused him to veer away from his previous honest ways (he lost his moral compass).

*Page 82: What you experience as a continuous, indivisible stream of perception is actually but the visible tip of the information-processing iceberg, most of which lies beneath the surface of your conscious awareness.* Myers is making an analogy here. Most of the important functions that allow you to see the world as a whole are not part of conscious experience, but, like most of the mass of an iceberg, are below the surface and out of awareness.

*Page 84:* Waking from the surgery, one patient even managed to *quip* that he had a *"splitting headache"* . . . . People have had their corpus callosum severed or cut in order to control epileptic seizures. Despite such a major operation this patient managed to joke (*quip*) that he had a very bad headache (*a splitting headache*). Personality and intellectual functioning were not affected by this procedure, and you would

not be able to detect anything unusual if you were having a casual conversation with a split-brain patient.

*Page 85:* When the "two minds" are at odds, the left hemisphere does *mental gymnastics* to *rationalize* reactions it does not understand. In split-brain patients, if information or commands are delivered to the right hemisphere (which does not have language), then the left hemisphere, which can talk, would not be aware of what was requested. So if the patient carried out the command to do something (e.g., "walk" or "clap"), the left hemisphere will go through all kinds of contortions (*mental gymnastics*) to create some plausible story that accounts for the response (it rationalizes and constructs theories to explain our behavior).

*Page 87:* When at their worst, they distort a *pretzel-shaped finding* into a *breadstick-shaped story*: Some people are left-brained, others right-brained. . . . A *pretzel* is a snack food, a piece of thinly rolled bread dough shaped like an open knot. A unique and unusual set of findings (*pretzel-shaped*) gets transformed through the process of oversimplification and distortion into something totally different (*a breadstick-shaped* [very straight] *story*). Thus, public myths, such as *"some people are left-brained, others right brained,"* develop and get more attention than the scientific facts.

*Page 88:* From simply looking at the two hemispheres, which *appear alike* to the *naked eye,* who would suppose that they contribute so uniquely to *the harmony of the whole?* Myers points out that research with split-brain people and normal people shows that we have unified brains with different parts that have specialized functions. Thus, if we observe the two hemispheres without optical aids (*with the naked eye*), they may seem to be the same (*appear alike*); however, their differential functioning combines to produce an integrated unit (*the harmony of the whole*).

*Page 89: . . . southpaws . . .* Left-handed people, especially those involved in sports such as boxing or baseball, are called *southpaws.* Stanley Coren found that the percentage of left-handers (*southpaws*) in the population declines with age. This finding is still somewhat mysterious.

*Page 91:* Yet what is unknown still *dwarfs* what is known. This means that all that has been discovered so far is very, very small (*dwarfed*) compared to what yet remains to be discovered.